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Annual early spring burning has markedly altered the physiognomy and species composition of aspen parkland vegetation of east-central Alberta. Burning was conducted in April for at least 24 years when soil moisture was normally high. The number of herbaceous species per quadrat doubled while a number of woody species declined slightly. Forest cover declined while grassland increased. In the grass and shrublands, cover of the shrub *Symphoricarpos occidentalis* and the cool season grass *Festuca scabrella* declined greatly. Major increases in *Calamovilfa longifolia*, *Carex obtusata*, *C. heliophylla*, and *Solidago missouriensis* were noted. While the cover of *Festuca scabrella* and *Stipa spartea* var. *curtiseta* decreased; frequency of these species increased. Cover of all shrubs decreased, *Populus tremuloides* suckers excepted, while density of the fire adapted *Elaeagnus commutata*, *Amelanchier alnifolia*, *Prunus virginiana*, and *Populus tremuloides* suckers increased. Burning reduced the leaf blade length of all major grasses and sedges. Effect of burning on inflorescence production varied from species to species. Annual herbage production was reduced by burning with the grass and sedge component experiencing about a 50% reduction. Burning caused an increase in organic matter and phosphorus content of the Ah horizon. Burning did not appear to detrimentally affect the nitrogen status of the Ah horizon.

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Le brûlage annuel au début du printemps a altéré de façon marquée la physionomie et la composition floristique de la végétation de l'*aspen parkland* au centre-est de l'Alberta. Le brûlage a été effectué pendant au moins 24 ans en avril, au moment où l'humidité du sol est normalement élevée. Le nombre d'espèces herbacées par quadrat a doublé, tandis que plusieurs espèces ligneuses ont légèrement diminué. Le couvert de la forêt a diminué et celui de la prairie a augmenté. Dans les prairies et les zones arbustives, le couvert de l'arbuste *Symphoricarpos occidentalis* et de la graminée *Festuca scabrella* a fortement diminué. Les espèces qui ont accusé la plus forte augmentation sont *Calamovilfa longifolia*, *Carex obtusata*, *C. heliophylla* et *Solidago missouriensis*. Alors que le couvert de *Festuca scabrella* et de *Stipa spartea* var. *curtiseta* diminuait, leur fréquence augmentait. Le couvert de tous les arbustes, sauf les drageons de *Populus tremuloides*, a diminué, alors que la densité augmentait chez les espèces suivantes, adaptées au feu: *Elaeagnus commutata*, *Amelanchier alnifolia*, *Prunus virginiana*, ainsi que chez les drageons de *Populus tremuloides*. Le brûlage a réduit la longueur du limbe foliaire chez toutes les principales Graminées et Cypéracées. L'effet du brûlage sur la production d'inflorescences diffère d'une espèce à l'autre. Le brûlage a réduit la production annuelle d'herbes, les Graminées et les Cypéracées subissant une réduction d'environ 50%. Il a provoqué une augmentation de la matière organique et de la teneur en phosphore de l'horizon Ah. Il ne semble pas avoir eu d'effet nuisible sur la condition de l'azote dans l'horizon Ah.

[Traduit par le journal]

Introduction

Fire played a significant role in the aspen park-nd of western Canada prior to white settlement Nelson and England 1971). The frequency of rning declined following this settlement. Subsequently, woody vegetation has encroached into e adjacent grasslands (Coupland and Maini 1959; iley and Wroe 1974; Scheffler 1976). The effect a single fire on grasslands has been reported in ny studies (Daubenmire 1968); a single fall or ring burn in the *Festuca – Stipa* grassland of the central Alberta aspen parkland was reported by Bailey and Anderson (1978). There are few studies, however, of the effect of annual burning on grasslands and none of the effect of annual burning on a northern prairie dominated by a cool season grass like *Festuca scabrella*.

This study examined the effect of annual early spring burning on species composition and standing crop of native grassland vegetation in the aspen parkland of central Alberta.

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Study area

The following criteria were relied upon in selecting a suitable study area: (*i*) burning must

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have been of sufficient frequency to produce an ecosystem adapted to fire; (*ii*) burned and unburned areas must be in close proximity so that paired comparisons could be made on similar soils and topography; (*iii*) grazing, browsing, and other disturbances must have been of minor significance. The Camp Wainwright Military Reserve, approximately 192 km southeast of Edmonton, Alta., met these requirements. Study sites were confined to Tp. 44 R. 7 W4M (Fig. 1). Topography was undulating to gently rolling. Mean elevation was approximately 610 m. Predominant landforms consisted of kames and kame moraines (Bayrock 1967). The orthic or rego black, or dark brown, chernozemic soils had sand or sandy loam textures (Wyatt *et al.* 1944). The vegetation was a complex mosaic of groves of *Populus tremuloides* groves and grasslands dominated by *Festuca scabrella* and *Stipa spartea* var. *curtiseta*. Tree density ranged from 2500 to 15 200 stems/ha. Basal area in

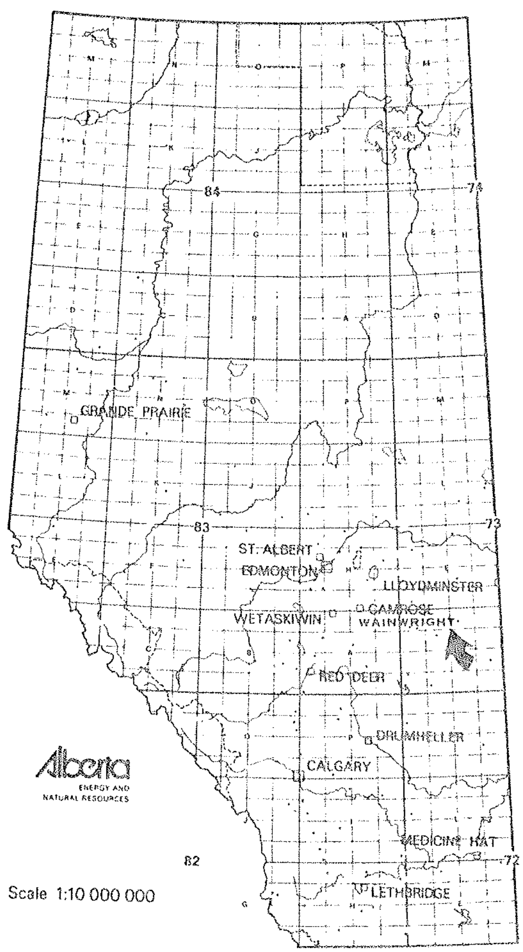

FIG. 1. Location of the study area.

dense young stands was less than 0.5 m²/ha whereas in older stands it ranged from 1.7 to 2.1 m²/ha. Shrubs (*Symphoricarpos occidentalis*, *Elaeagnus commutata*) were common in the grassland. In Saskatchewan, Coupland and Brayshaw (1953) have described this vegetation mosaic. *Festuca* attains its optimum development on lower slopes of north or east exposure (Ayyad and Dix 1964; Cosby 1964).

Annual precipitation at Fabyan, 13.5 km north-northwest, averaged 451 mm with the monthly maximum of 108 mm occurring during June (Atmospheric Environment Service 1976). Approximately 65% of annual precipitation occurred between May 1 and September 30. Annual mean daily temperatures at Heath, 25 km east-northeast, averaged 2.9°C with May to September (inclusive) values averaging 13.5°C.

An annually burned core area of approximately 8100 ha was surrounded by unburned stands of native vegetation. Burned and unburned areas were separated by a road and fire guard.

Methods

Four pairs of 2 m wide belt transects totalling 1480 m in length were established in burned and unburned areas. The transects covered a range of topographic, edaphic, and vegetation conditions in grassland and shrubland in each treatment. The proportion of moist and dry sites sampled on burned and unburned areas was approximately equal. Transects were randomly located within areas undisturbed by military vehicles or explosives.

Composition of grasses, sedges, forbs, and low shrubs (<0.1 dm height) was estimated in July and August 1976, using 916 quadrats, 0.1 m × 0.1 m, randomly located within the transects. Canopy cover (class midpoints 2.5, 7.5, 17.5, 37.5, 62.5, 85, and 97.5%), number of inflorescences and average maximum leaf blade lengths of major grasses and sedges were recorded in each quadrat. Shrub cover and density were recorded from 7[illegible] quadrats, 0.5 m × 0.5 m, randomly located within each transect. Species nomenclature follows Moss (1959).

Estimates of standing crop of grass- and shrub-dominated communities were obtained from two replicate quadrats, 0.5 m × 0.5 m, within each transect (16 quadrats in total). Vegetation was clipped at ground level in mid-August 1976, field sorted into components (shrub, grass, forb, litter), subsequently oven dried, and weighed.

The nutrient status (K, P, Ca), fibre percentage, and moisture content of current-year grass foliage was determined in mid-August on burned and unburned areas from three sites on two transects (upper and lower slope positions on southerly exposures and upper slope positions on a northerly exposure).

Standard soil analyses (K, P, nitrate N, Na, S, and pH) were carried out for A and B horizons from two slope positions (upper and lower south exposures) on burned and unburned transects. In addition samples of the Ah horizon were collected during the 3rd week in October when nitrogen levels were stable (Eagle and Mathews 1958). The Ah was separated into an upper portion (0–5 cm depth, less compact, and not well decomposed) and lower portion (6–15 cm depth, more compact, and well decomposed). Three sites were selected from each of the two treatments, each site consisting of two pits with three replicates taken from each pit. Organic matter content was determined by loss on ignition. Nitrogen supplying power of the Ah horizon was assessed by a technique similar to one described by Eagle and Mathews (1958). Half of each sample was incubated at 37°C for 4 weeks with moisture contents maintained at or near field capacity. Nitrate and ammonia forms of nitrogen were determined by steam distillation (Bremmer 1965).

Statistical comparisons of burned with unburned areas were made by analysis of variance and Duncan's multiple range test.

Results

Species diversity (number of species per unit area) generally increased with burning in grass and shrubland (Table 1). Burned areas had twice as many grass and sedge species as unburned ones. The number of forb species also increased with burning. There was a marginal decrease in the number of shrub species. Annual early spring burning reduced the proportion of forest and has resulted in a considerable expansion of grassland (Figs. 2 and 3). This spring burning has also checked the invasion of *Populus tremuloides* into grassland (Fig. 4). Shrub height was reduced markedly.

Cover of herbaceous species frequently increased with burning of grass and shrublands while most woody species declined (Table 2). Amongst the grasses, the increasers were primarily species adapted to the northern mixed prairies. *Calamovilfa longifolia*, a species well adapted to sandy soils, increased greatly in canopy cover and frequency. Although *Bouteloua gracilis* and *Agropyron smithii* did not occur in unburned areas, they were present in at least 10% of the quadrats in burned areas. *Carex obtusata* and *C. heliophila*, two early growing sedges, increased sharply under burning. *Solidago missouriensis* was the forb which increased the most under annual spring burning.

Under burning, decreasers in cover included dominant species of the unburned grassland. Major species included the grasses *Festuca scabrella*, *Stipa spartea* var. *curtiseta*, the sedge *Carex siccata*, and the shrubs *Symphoricarpos occidentalis*, *Elaeagnus commutata*, *Amelanchier alnifolia*, *Rubus strigosus*, and two species of *Rosa*. The only woody species that increased in cover under burning were the suckers of *Populus tremuloides* and the half-shrub *Artemisia frigida*.

TABLE 1. Species diversity in unburned and burned areas (quadrat size: herbs = 0.1 m^2, shrub = 0.5 m^2) (n = 343–573)

	Unburned	Burned
Grasses and sedges	2.2	4.6
Forbs	2.5	4.0
Grasses, sedges, and forbs	4.7	8.6
Shrubs	2.0	1.7

Changes in frequency largely coincided with the changes in cover. There were some notable exceptions, however, among the major species. Three shrubs, *Elaeagnus commutata*, *Rosa arkansana*, and *Amelanchier alnifolia* showed a decrease in cover but an increase in frequency due to burning. *Prunus virginiana* frequency increased with burning but cover did not change. The two dominant grasses, *Festuca scabrella* and *Stipa spartea* var. *curtiseta*, showed an increase in frequency but a decrease in cover due to fire. *Galium boreale* frequency showed no change due to fire while cover increased. *Smilacina stellata* frequency increased due to fire with cover showing no change.

Density of three shrubs decreased under burning, four major shrubs increased, and four species did not change (Table 3). The highest mean stem density encountered was for *Symphoricarpos occidentalis* in either burned or unburned areas.

Burning reduced blade length of major grass and sedge species (Table 4). *Festuca scabrella*, *Stipa spartea* var. *curtiseta*, and *Agropyron subsecundum* had the greatest reduction in blade length.

Two aspects of inflorescence production were affected by burning (Table 5). Percentage presence of seed heads was higher on the burned area for *Muhlenbergia richardsonis*, *M. glomerata*, *Calamovilfa longifolia*, *Bouteloua gracilis*, and *Koeleria cristata*. Seed head density was higher on the burned treatment for *Muhlenbergia richardsonis*, *M. glomerata*, *Carex siccata*, *Agrostis scabra*, *Bouteloua gracilis*, and *Carex obtusata*. Highest seed head density for *Stipa spartea* var. *curtiseta* and *Festuca scabrella* occurred on the unburned treatment. Flowering in *Agropyron subsecundum* appeared unaffected by burning.

Annual burning substantially reduced aboveground biomass (Table 6). Standing crop of shrubs was reduced the most but grasses and sedges were reduced by about 50%. Burning kept litter at a very low level.

In August, the nutrients N, P, K, and Ca were not significantly different in grass and sedge foliage between burned and unburned areas. Crude fibre was significantly lower ($P < 0.05$) in burned areas (18.9 versus 20.5%).

Soil tests revealed no difference between burned and unburned areas for N, K, S, Na, and pH. However, the number of samples was small (n = 4). Phosphorus was significantly greater ($P < 0.05$) in the Ah horizon of burned areas (11.2 versus 6.7 kg/ha).

The organic matter content of Ah horizons was

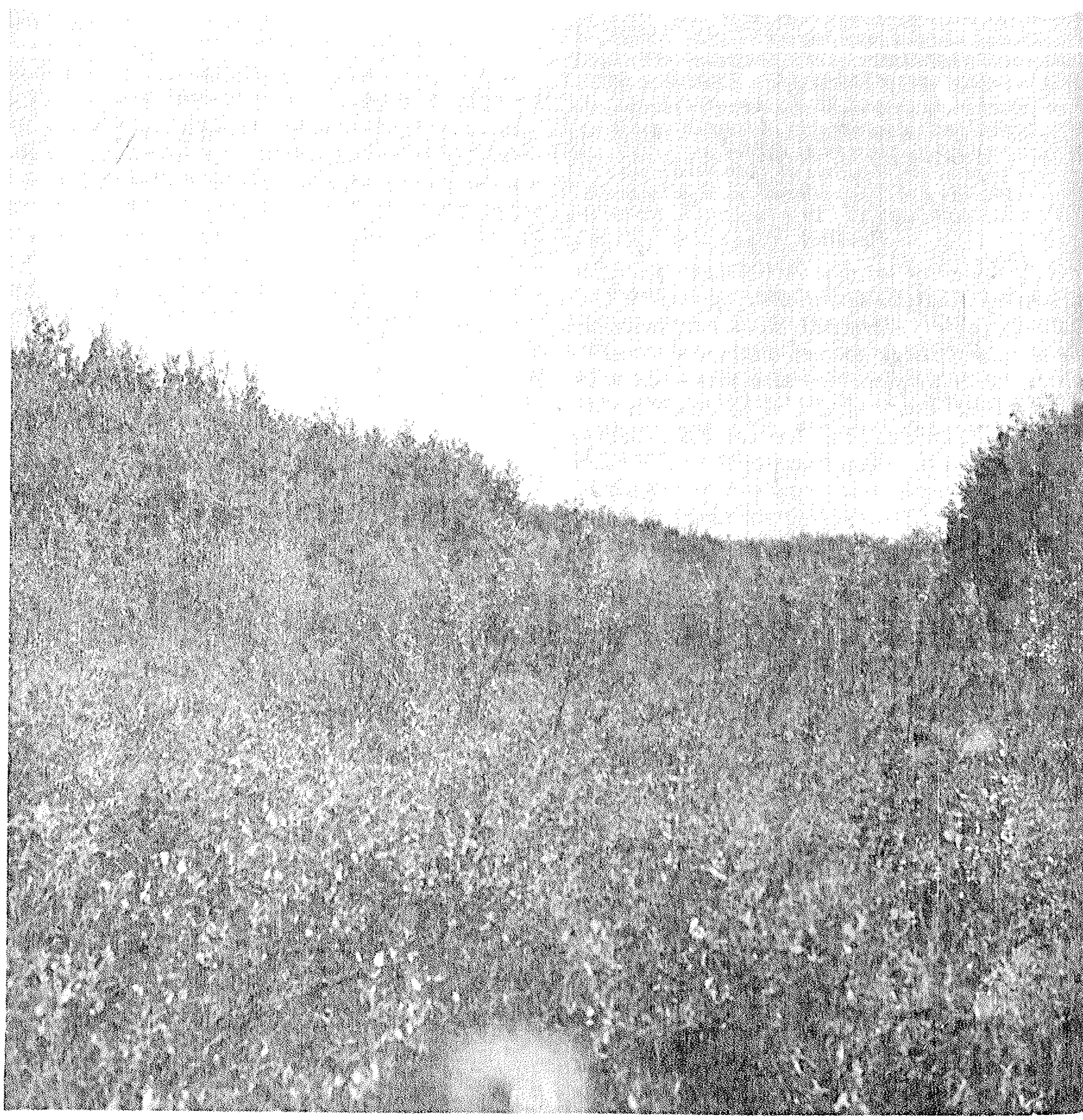

FIG. 2. Unburned vegetation with dense cover of *Elaeagnus*, *Symphoricarpos*, and *Festuca* between *Populus* groves.

greater in burned than unburned areas (Table 7). There was little difference in bulk density between burned and unburned areas. Under field conditions, the dominant form of nitrogen was ammonia (Table 8). After incubation of the surface soil, however, nitrate nitrogen became the dominant form. Total nitrogen (ammonia plus nitrate) supplying power of the surface soil was not materially altered by annual burning.

Discussion

The historical review by Nelson and England (1971) documented the high frequency of fire on Canadian prairie grasslands prior to settlement. Presettlement repeated burning maintained or expanded grassland at the expense of forest in many areas. The present study quantifies some of these early observations. Annual early spring burning did not eliminate any woody species since all sprouted after fire. All woody plants studied were adapted to spring fire. These have developed in a grassland where fire was one of the environmental components of the ecosystem. It has been cessation of this natural environmental component that has resulted in sharp changes in the vegetation mosaic. Fire is a useful tool in maintaining grass dominance in envi-

FIG. 3. Vegetation burned annually in early spring. Grassland has a high density of *Elaeagnus*. Fire has not burned through and killed trees in *Populus* grove on extreme left of photograph but has burned amongst all other trees.

onments where woody species invade grasslands (Daubenmire 1968).

Annual burning caused an increase in the number of grass, sedge, and forb species. Forbs are generally enhanced by burning (Hensel 1923; Daubenmire 1968). Annual burning prevented litter accumulation on grasslands. The more exposed soil surface in burned areas would be a more favourable seedbed than in unburned areas. Similar results were found by Anderson and Bailey (1979) after a single burn in a *Symphoricarpos occidentalis* community. High temperatures were realized when the shrubs burned (Bailey and Anderson 1980) consuming the shrubs, creating a favourable seedbed, and reducing plant competition for seedlings. However, a single burn in adjacent grassland gave different results. Bailey and Anderson (1978) found little change in the number of species after one spring or fall burn in *Festuca – Stipa* grassland. It apparently requires more than one spring or fall fire to create a favourable seedbed.

In grasslands, the major decreasers in canopy cover were the shrub *Symphoricarpos occidentalis* and the cool season grass *Festuca scabrella*. An-

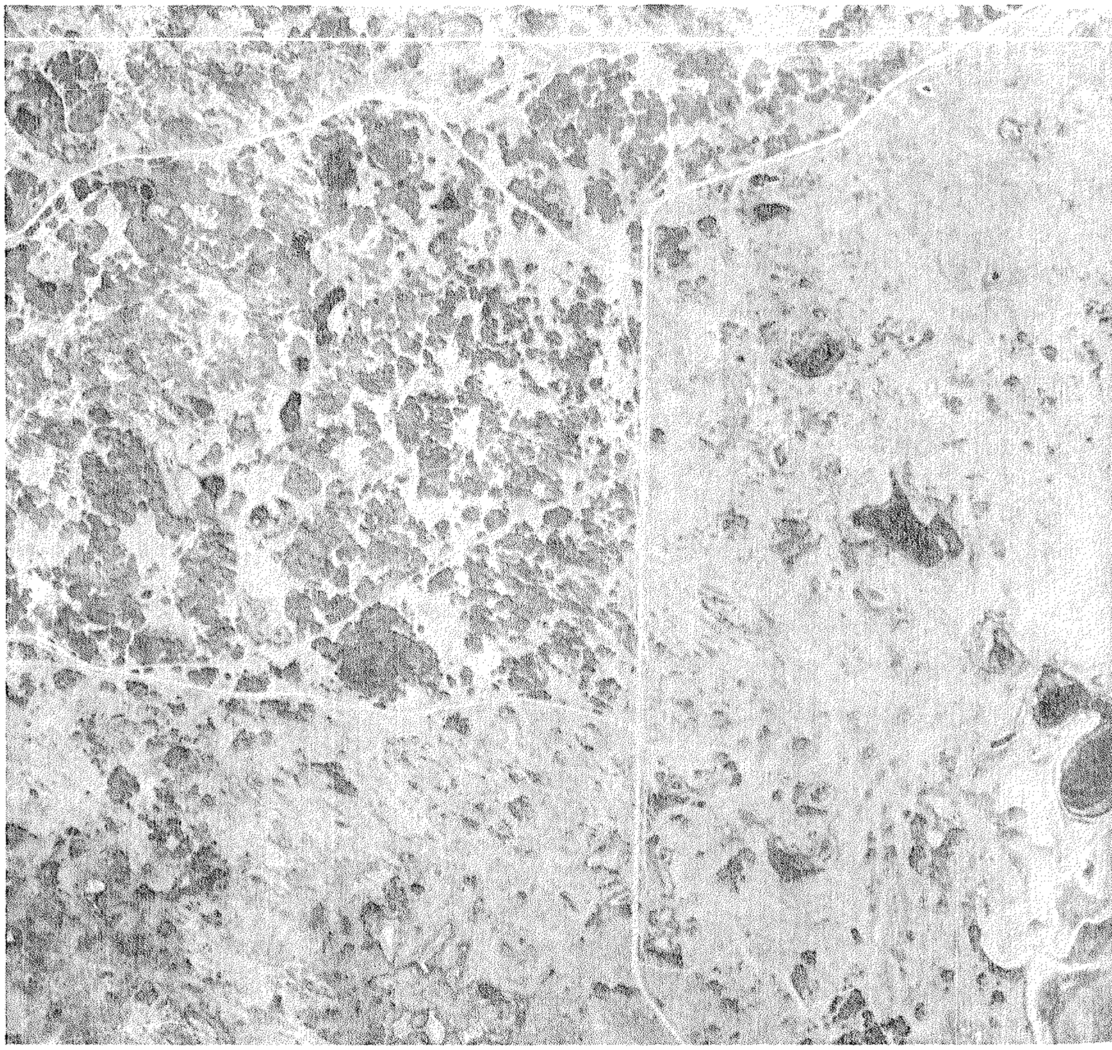

FIG. 4. Aerial photograph showing unburned (upper left) and burned aspen parkland vegetation (right and lower left) (Alberta Energy and Natural Resources, 1975, photo No. AS1417-165, scale 1 : 31 680).

nual burning killed many stems of *Symphoricarpos* each year but the root system was not killed. In British Columbia, McLean (1969) classified *Symphoricarpos albus* as having a root and rhizome system that made it resistant to wild fires. In Kansas, annual early spring burning reduced stem density of *Symphoricarpos orbiculatus*, while late spring burning eliminated the shrub (Smith and Owensby 1972).

Burning has resulted in a shift from a relatively few large plants to many small plants. The frequency increases following burning are attributable to increased resprouting by shrubs and increased tiller production in grasses. The shorter blade length of grasses in burned areas probably accounts for the decline in canopy cover.

The deleterious effects of early spring fires on cool season grasses has been reported many times (e.g., Hensel 1923; Robocker and Miller 1955; Ehrenreich and Aikman 1963). *Festuca scabrella* initiated growth early in spring. Bailey and Anderson (1978) found that a single spring burn reduced *Festuca* canopy cover more so than a single fall burn. They found that *Festuca* inflorescence production was sharply reduced by a spring burn but not affected by a fall burn. Early spring annual burning decreased *Festuca* cover, blade length, and eliminated seed production but its frequency of occurrence increased. *Festuca* is the major contributor to grass biomass production in unburned areas. Since tiller density and canopy height were the primary criteria influencing yield in *Bromus* *inermis* (Tan *et al.* 1977), it is likely that reduced canopy cover and blade length of *Festuca* was an important factor in the lower grass and sedge production component of standing crop in burned areas. It is evident that *Festuca* is well adapted to surviving annual early spring burning. Bailey and Anderson (1978) found that a single spring burn reduced *Festuca* canopy cover but did not reduce annual herbage production. In this study we have found that annual burning reduced *Festuca* canopy cover and annual herbage production. The land manager should investigate the use of periodic, rather than annual, early spring burning if maximum *Festuca* production is an objective.

The 50% reduction in cover of *Festuca scabrella* was one of the largest noted for any species. *Festuca* also did not produce seed heads under annual spring burning. Moss (1955) noted that the botanist John Macoun failed to record *Festuca scabrella* in the aspen parkland in the 1880's (Macoun 1882), although he did observe a *Festuca* in the Cypress Hills. The scarcity of seed heads and low canopy cover of *Festuca* associated with frequent fire may explain Macoun's observation. The reduction in fire frequency following settlement may have been favourable for the increased importance of *Festuca scabrella* during the twentieth century. Macoun (1882) considered "northern buffalo grass" (*Stipa spartea* var. *curtiseta*) as the dominant grass of the aspen parkland region.

Annual early spring burning does favour certain cool season plants. The grasses *Helictotrichon hookeri* and *Agropyron smithii* and the sedges *Carex obtusata* and *C. heliophylla* increased in both frequency and canopy cover. Season of growth initiation was not the only factor influencing plant response to burning. Grassland fires tend to create a more arid environment because of less litter cover and lower soil moisture status (DeJong and MacDonald 1975). Grasses adapted to drier environments are favoured over species adapted to more mesic conditions. All grasses classified as increasers in Table 2 are found in the mixed prairie (Coupland 1950). Annual early spring burning has caused a shift in grass and sedge species composition away from species of the *Festuca scabrella* grasslands in favour of species from the mixed prairie association.

The warm season mixed prairie grasses, *Calamovilfa longifolia*, *Oryzopsis hymenoides*, *Muhlenbergia richardsonis*, and *Bouteloua gracilis*, all do well on disturbed sites and on sandy soils. They start growth late in the spring and flower late in the season. *Solidago missouriensis*, the forb most beneficially affected by annual burning, also flowers late in the growing season. The two low-growing sedges favoured by fire start growth and flower early. They may have responded to a reduction in competition because of reduced cover and blade length of dominant grasses; this may more than offset any deleterious effects of early spring fire.

Response of *Stipa spartea* var. *curtiseta* to fire is intermediate between the warm season mixed prairie grasses such as *Calamovilfa longifolia* and the cool season grasses such as *Festuca scabrella* or *Agropyron subsecundum*. This *Stipa* species is the codominant of the *Stipa – Agropyron* faciation (Coupland 1950), the most mesic community of the northern mixed prairie. *Stipa* starts growth later than *Festuca*. A single spring burn did not affect *Stipa* canopy cover and it stimulated inflorescence production for 3 years, whereas a single fall burn reduced cover and seed heads (Bailey and Anderson 1978). An increase in aridity should favour *Stipa* over *Festuca*. This is the case. In burned areas, the percentage reduction in canopy cover, blade length, and seed-head density was less in *Stipa* than in *Festuca*.

The effect of burning on herbage yields is variable. Hensel (1923) reported a reduction in yield of an *Andropogon – Bouteloua – Poa* prairie while in a more mesic area, Iowa, an increase in an *Andropogon – Sorghastrum* prairie was evident (Ehrenreich and Aikman 1963). Coupland (1973) found a reduction in herbage yields for 3 years after an *Agropyron – Koeleria* community was burned by August wildfire. Bailey and Anderson (1978) reported no significant change in herbage production after either a single spring or fall prescribed burn in *Festuca – Stipa* grassland. Annual herbage production in unburned areas of the present study was similar to those reported by Bailey (1970) and Bailey and Anderson (1978) for the *Festuca – Stipa* community 50 km northwest of the present study area. In his review, Daubenmire (1968) noted that burning of warm season grasses in mesic parts of the Great Plains caused an increase in herbage production while burning in arid parts of the Great Plains caused a decrease in herbage. In Africa, West (1965) observed that fire increased production in more moist regions but was generally detrimental in more arid regions. In Texas, Wright (1972) and Wink and Wright (1973) found that one prescribed burn during a wet year stimulated production whereas a burn during a dry year caused a further reduction in yield. In our study, annual burning favoured a species change towards plants adapted to more arid areas. Annual herbage production probably declined mainly as a result of a decline in

TABLE 2. Frequency and canopy cover of common species on burned and unburned grass and shrublands

Species*	Frequency, %		Canopy cover, %	
	Unburned (n = 458)	Burned (n = 458)	Unburned (n = 458)	Burned (n = 458)
Grasses				
Decreasers				
Festuca scabrella	65	82	36*a*	18*b*
Stipa spartea var. *curtiseta*	45	68	15*c*	11*d*
Agropyron subsecundum	30	20	3*a*	1.2*b*
Stipa viridula	6	0	1.6*a*	0*b*
Bromus inermis	5	2	1.2*c*	0.2*d*
Bromus ciliatus	4	1	0.3*c*	+*d*
Increasers				
Calamovilfa longifolia	3	49	0.7*b*	41*a*
Helictotrichon hookeri	2	48	0.1*b*	2*a*
Oryzopsis hymenoides	3	16	0.1*b*	0.6*a*
Muhlenbergia richardsonis	2	4	0.9*d*	1.3*c*
Bouteloua gracilis	0	13	0*b*	1.3*a*
Agropyron smithii	0	10	0*b*	0.5*a*
Sedges and rushes				
Decreasers				
Carex siccata	14	3	4*a*	0.5*b*
Carex deflexa	6	0	1.1*a*	0*b*
Carex spp.	3	0	0.9*c*	0*d*
Carex douglasii	4	0	0.7*c*	0*d*
Increasers				
Carex obtusata	10	91	1.1*b*	18*a*
Carex heliophila	+	26	+*b*†	14*a*
No change				
Carex peckii	2	1	0.5*a*	0.1*a*
Juncus balticus	3	3	0.2*a*	0.1*a*
Forbs				
Decreasers				
Aster laevis var. *geyeri*	9	6	1.2*e*	0.5*f*
Equisetum laevigatum	15	8	0.5*e*	0.3*f*
Agoseris glauca	5	2	0.6*a*	0.1*b*
Lathyrus ochroleucus	3	+	0.2*a*	+*b*
Anemone patens	2	5	0.1*a*	+*b*
Astragalus striatus	5	2	0.2*e*	0.1*f*
Increasers				
Solidago missouriensis	18	50	1.7*b*	27*a*
Thermopsis rhombifolia	14	47	0.7*b*	3*a*
Achillea millefolium	23	36	1.1*b*	3*a*
Galium boreale	22	20	1.0*b*	4*a*
Lathyrus venosus	2	15	0.1*b*	1.2*a*
Commandra pallida	9	37	0.3*b*	2*a*
Monarda fistulosa	5	9	0.5*f*	1.3*e*
Artemisia ludoviciana	24	31	2*b*	3*a*
Campanula rotundifolia	17	24	0.5*f*	0.9*e*
Vicia americana	4	10	0.2*b*	0.5*a*
Vicia sparsifolia	4	8	0.1*f*	0.3*e*
No change				
Viola adunca	5	6	0.3*a*	0.5*a*
Aster pansus	4	6	0.4*a*	1.0*a*
Cirsium floodmanii	2	1	0.4*a*	0.1*a*
Smilacina stellata	4	7	0.3*a*	0.3*a*
Artemisia campestris	1	3	0.3*a*	0.2*a*
Fragaria virginiana	2	4	0.1*a*	0.2*a*
Thalictrum spp.	2	4	0.1*a*	0.1*a*

TABLE 2. (*Concluded*)

Species*	Frequency, % Unburned ($n = 458$)	Frequency, % Burned ($n = 458$)	Canopy cover, % Unburned ($n = 458$)	Canopy cover, % Burned ($n = 458$)
Shrubs				
Decreasers				
Symphoricarpos occidentalis	56	52	31*a*	2*b*
Elaeagnus commutata	20	34	4*a*	2*b*
Amelanchier alnifolia	8	16	4*a*	1.4*b*
Rosa acicularis	13	1	3*a*	0.4*b*
Rubus strigosus	5	2	1.2*a*	0.1*b*
Rosa arkansana	11	24	1.3*e*	0.6*f*
Increasers				
Populus tremuloides (suckers)	3	18	0.2*b*†	0.9*a*
Artemisia frigida	3	7	0.2*f*	0.3*e*
No change				
Prunus virginiana	6	15	1.9*a*	1.5*a*
Prunus pensylvanica	2	2	0.4*a*	0.1*a*

*The terms decreasers, increasers refer only to species that have had significant changes in canopy cover.
†Means in the same row followed by the same letter are not significantly different (*a–b* $P < 0.005$, *c–d* $P < 0.01$, *e–f* $P < 0.05$).
‡Plus (+) refers to less than 0.1% canopy cover.

TABLE 3. Effect of annual burning on shrub density (number per square metre)

Species	Unburned ($n = 385$)	Burned ($n = 343$)
Decreasers		
Symphoricarpos occidentalis	25.0*a**	17.8*b*
Rosa acicularis	1.4*c*	0.8*d*
Rubus strigosus	0.4*c*	0.2*d*
Increasers		
Elaeagnus commutata	1.2*b*	6.4*a*
Amelanchier alnifolia	1.2*b*	6.2*a*
Prunus virginiana	1.0*b*	4.2*a*
Populus tremuloides	0.2*b*	2.6*a*
No change		
Rosa arkansana	1.0*a*	1.2*a*
Spirea alba	0*a*	1.0*a*
Prunus pensylvanica	0.2*a*	0.2*a*
Lonicera dioica var *glaucescens*	+*a*†	+*a*

*Means in the same row followed by the same letter are not significantly different (*a–b* $P < 0.005$, *c–d* $P < 0.05$).
†Plus (+) is < 0.1 stems/m^2.

TABLE 4. Effect of annual burning on leaf blade length (cm) of dominant grasses and sedges

Species	Unburned *n*	Unburned Length	Burned *n*	Burned Length
Festuca scabrella	272	34*a**	282	14*b*
Stipa spartea var. *curtiseta*	135	29*a*	234	13*b*
Calamovilfa longifolia	25	29*a*	168	24*b*
Agropyron subsecundum	124	28*a*	69	14*b*
Carex siccata	30	32*c*	10	20*d*

*Means in the same row followed by the same letter are not significantly different (*a–b* $P < 0.005$, *c–d* $P < 0.05$).

blade length and cover of the dominant perennial grasses, *Festuca scabrella* and *Stipa spartea* var. *curtiseta*. The decline in blade length and canopy cover of *Festuca* and *Stipa* is probably closely related to the more arid microclimate caused by spring burning. Lower soil moisture levels on burned areas as compared with unburned areas were attributed to reduced infiltration rate and a reduction in soil moisture recharge during the winter period due to a loss of snow (DeJong and MacDonald 1975). There is probably a greater evaporation loss because of the absence of litter. These factors have a detrimental effect on the plant water status (Redmann 1978). He concluded that greater water stress in plants growing on an October burned site on a clay soil in the arid mixed prairie could explain the reductions in primary production. In this grassland at the northern extremes of the Great Plains, factors in addition to aridity are responsible for the decline of productivity under burning. Season of burning is very important and is poorly understood. It is known, however, that spring burning does detrimentally affect the cool season grass dominant, *Festuca scabrella* (Bailey and Anderson 1978).

Changes in shrub density largely reflect resprouting capacity and adaptation of each species to the new microclimate. Those shrubs showing increased density after burning have a high capacity to regenerate from suckers and can survive under the more arid conditions while those showing a decrease have a lower ability.

Elaeagnus commutata is a nitrogen-fixer (Vlas-

TABLE 5. Effect of annual burning on inflorescence production of common grasses and sedges

Species	Unburned			Burned		
	n*	Presence,† %	Density, no./m²	n	Presence, %	Density, no./m²
Muhlenbergia richardsonis	3	33	130	13	100	483
Carex siccata	1	3	10	4	10	150
Agrostis scabra	2	22	10	1	20	110
Calamovilfa longifolia	6	24	13	67	40	18
Bouteloua gracilis	0	0	0	25	56	44
Muhlenbergia glomerata	0	0	0	3	100	30
Carex obtusata	0	0	0	10	3	24
Agropyron subsecundum	28	23	14	17	25	15
Koeleria cristata	4	36	17*a*‡	8	73	14*b*
Poa interior	2	67	20	2	18	15
Stipa spartea var. *curtiseta*	43	32	23*a*	45	19	14*b*
Festuca scabrella	18	7	34	0	0	0

*Number of quadrats in which seed heads were present.
†The number of quadrats bearing seed heads expressed as a percentage of the total number of quadrats in which the species was found.
‡Means for density within a row followed by a different letter are significantly different at $P < 0.05$. All other means for density are not significantly different at $P < 0.05$.

TABLE 6. Components of aboveground biomass (kg/ha) for burned and unburned vegetation, August 1976 (oven-dry weights)

Component	Unburned		Burned	
	$\bar{x} \pm$ SE (n = 8)	% of total living	$\bar{x} \pm$ SE (n = 8)	% of total living
Shrub	3217*a** ± 1609	67	173*a* ± 171	15
Grass and sedge	1408*a* ± 181	30	719*b* ± 96	60
Forb	117*a* ± 40	3	295*a* ± 64	25
Total living	4742		1187	
Litter	4502*a* ± 327		262*b* ± 235	

*Mean values in same row followed by the same letter are not significantly different ($P < 0.005$).

TABLE 7. Organic matter content (%) of soil Ah horizons (n = 18–27)

Soil depth, cm	Unburned, $\bar{x} \pm$ SE	Burned, $\bar{x} \pm$ SE
0–5	10.41*b** ± 0.59	14.70*a* ± 1.10
6–15	5.83*b* ± 0.21	8.30*a* ± 0.37

*Values in a row followed by the same letter are not significantly different at $P < 0.005$.

sak *et al.* 1973) that can contribute significant quantities of nitrogen to the ecosystem (Whysong and Bailey 1975). *Elaeagnus* can tolerate more arid conditions than found on the study area since it is common in parts of the mixed prairie (Coupland 1950). *Amelanchier alnifolia* and *Rosa arkansana* also occur in more arid areas. However, *Rosa acicularis* and *Rubus strigosus* are more commonly found growing in the shade of *Populus tremuloides* groves rather than in the grasslands of the mixed prairie.

Numerous studies have linked fire with loss of organic matter and soil nitrogen (e.g., Isaac an[d] Hopkins 1937; Youngberg 1953; Austin an[d] Baisinger 1955; Dyrness and Youngberg 1957). This may be the norm after summer forest fires b[ut] may not apply in grassland regions. In his review Daubenmire (1968) cited several studies from th[e] coastal plain of the southeastern United States which indicated increased organic matter content following prescribed burning. There was a trend fo[r] organic matter to increase under prescribed burning in more moist areas but to decrease in more ar[id] areas. Season of prescribed burning and soil moisture status also affects subsequent soil organic matter levels. In Kansas, Owensby and Wyr[ill] (1973) found that under moist soil conditions [of] winter or early spring burning, soil organic matter levels were higher than under unburned or la[te] spring burned areas. Early spring annual burning [in] our study resulted in an increase in soil organic matter levels in both the 0–5 and 6–15 cm depths [of] the Ah horizon. The increase in organic matter [in] the Ah horizon may be related to a shift in rooti[ng]

TABLE 8. Nitrogen status and nitrogen supplying power (ppm) of Ah horizons of grassland soils

Soil depth, cm	Unburned (n = 2) Preincubation level NH⁴⁺N	NO³N	Ammonia + nitrate	Unburned Postincubation level NH⁴⁺N	NO³N	Ammonia + nitrate	Burned (n = 3) Preincubation level NH⁴⁺N	NO³N	Ammonia + nitrate	Burned Postincubation level NH⁴⁺N	NO³N	Ammonia + nitrate
0–5	21	4.5	25	36*	94†	130	18	6.0	24	10*	185†	195
6–15	14	2.2	16	13	30	43	19	2.5	21	33	29	62

*Significantly different at $P < 0.05$.
†Significantly different at $P < 0.005$.

depth. Smoliak *et al.* (1972) found a shift in root concentration towards the soil surface under heavy grazing of a *Stipa – Bouteloua – Agropyron* community of the mixed prairie. Sharrow and Wright (1977) indicated that the higher levels of organic matter in Ah horizons of burned sites resulted from higher soil temperature largely due to litter removal. Dead vegetation and roots would decompose more readily.

Nitrogen and sulfur can be volatilized during combustion; the other elements are released and are not directly lost from the ecosystem (Daubenmire 1968). We found only phosphorus higher in the Ah horizon under burning. Ehrenreich and Aikman (1963) indicated that available P was higher in soil on burned areas largely because of the destruction of organic matter by fire. This was probably not the case in our study where burning was conducted soon after snowmelt when soils were moist. More available P is likely caused by a more rapid turnover rate of organic matter due to the higher soil temperatures.

Burning apparently increases the nitrogen supplying power of the Ah horizon but does not adversely affect the nitrogen status of the soil. Other studies support this conclusion (Norman and Wetselaar 1960; Ehrenreich and Aikman 1963; Daubenmire 1968). Owensby and Wyrill (1973) demonstrated that nitrogen levels of plots burned in early spring were not different from unburned controls. Sharrow and Wright (1977) found that burning did not affect total N in the upper 2.5 cm depth but lowered total N levels in the 2.5–12.5 cm depth interval. Nitrogen is added to the upper soil from the charred material and the nutrients from the ash along with the warmer soil temperatures which stimulate some nitrogen depletion from lower layers by active organic decay.

Burned samples had a higher net mineralization rate of nitrogen (rate of ammonification less that of assimilation by microorganisms) in the laboratory than unburned samples. It is uncertain whether this phenomenon will occur under field conditions. This response may result from narrower C:N ratio in the organic material on burned areas.

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